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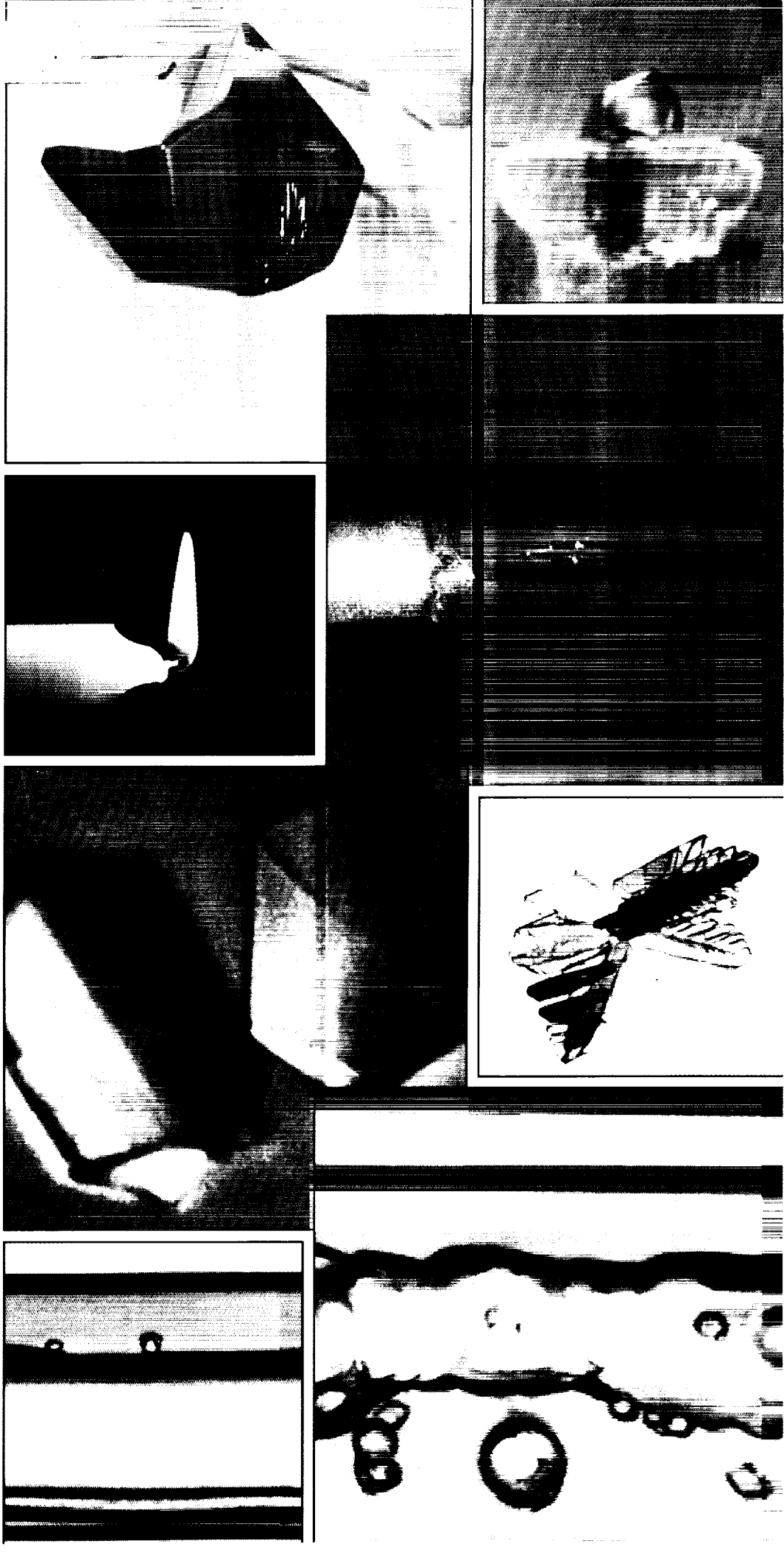
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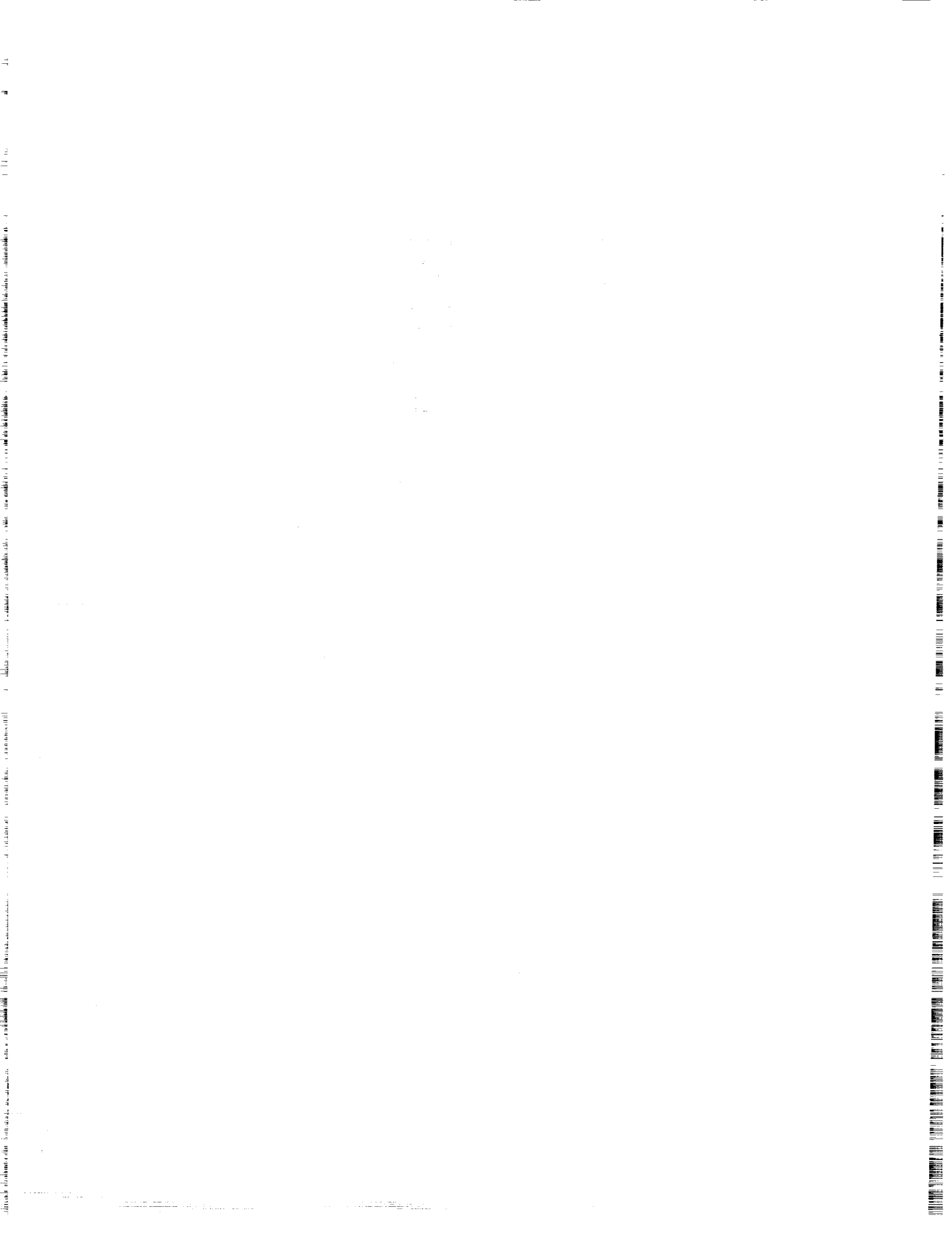
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(NASA-TM-108775) NASA MICROGRAVITY
SCIENCE AND APPLICATIONS PROGRAM
Annual Report, 1992 (NASA) 48 p

NASA

MICROGRAVITY
SCIENCE AND
APPLICATIONS
PROGRAM
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**ANNUAL
REPORT**





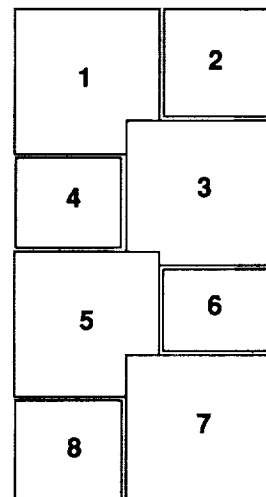
NASA

MICROGRAVITY
SCIENCE AND
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ANNUAL REPORT

On March 18, 1993 the NASA Administrator presented an Agency Group Achievement Award to the NASA Microgravity Program Science and Management Team in recognition of their outstanding 1992 accomplishments in support of the rapid growth and unprecedented scientific and engineering success of NASA's Microgravity Science and Applications Program.

Description of Cover Photographs: **Materials Science:** Mercuric iodide crystals grown in microgravity (1) have fewer defects and greater purity than those grown on Earth (2); **Combustion Science:** The spherical shape of a flame in microgravity (3) is distinctly different than a flame on Earth (4); **Biotechnology:** Isocitrate Lyase crystals grown in microgravity (5) demonstrate good morphology (shape) and molecular ordering allowing more accurate structure determination than crystals grown on Earth (6); **Fluid Physics:** In microgravity (7), air bubbles remain mixed with a flowing liquid, whereas air rises above the liquid on Earth (8).



Executive Summary

In the 1987 NASA report of the Microgravity Materials Science Assessment Task Force, the United States effort was said to lag behind the European and Japanese microgravity science space research programs.

By the end of 1992, NASA's Microgravity Science Program had established itself as the undisputed international standard of excellence in peer-reviewed, hands-on, space-based microgravity research.

The challenges faced and the progress achieved by NASA's Microgravity Science Research Program during 1992 were unprecedented.

NASA'S MICROGRAVITY SCIENCE PROGRAM FUNDS RESEARCH BY PRINCIPAL INVESTIGATORS WITHIN ACADEMIC DEPARTMENTS OF COLLEGES AND UNIVERSITIES IN 31 STATES AND THE DISTRICT OF COLUMBIA. Four NASA Research Announcements (NRAs), released in the fall of 1991, resulted in a total of 490 proposals received and peer-reviewed in 1992 by panels involving 129 independent discipline experts. The level of activity in 1992 exceeded the cumulative science proposals received in response to NASA microgravity announcements of opportunity since 1976. In October 1992, NASA awarded approximately \$15 million dollars for 124 microgravity research grants. These new grants represented an increase of 70 percent in the number of investigators sponsored by NASA's Microgravity Science and Applications Division (MSAD) and over three times the number of grants awarded in any previous year.

IN 1992, NASA'S MICROGRAVITY SCIENCE PROGRAM CONDUCTED MORE PEER-REVIEWED, HANDS-ON U.S. MICROGRAVITY SCIENCE RESEARCH IN SPACE THAN PERFORMED CUMULATIVELY IN ALL PRIOR YEARS SINCE SKYLAB (1973-74). Instruments for four Shuttle missions were developed, delivered, and integrated into the Spacelab and Shuttle on schedule and operated successfully on-orbit. The missions were the 8-day International Microgravity Laboratory (IML-1) in January 1992, the 14-day United States Microgravity Laboratory (USML-1) (the first Space Shuttle flight wholly dedicated to microgravity science) in June 1992, the 8-day Japanese dedicated Spacelab (SL-J) in September 1992, and the 9-day United States Microgravity Payload (USMP-1) in October 1992.

THE MUCH-APPLAUDED USML-1 PROGRAM REPRESENTED THE SYNTHESIS OF PROGRAM SCIENCE AND PROGRAM MANAGEMENT SKILLS RESULTING IN NEW APPROACHES TO MEET A CHALLENGING USML-1 LAUNCH COMMITMENT MADE TO THE CONGRESS IN 1988. Three major flight experiments, the Crystal Growth Furnace (CGF) from the Marshall Space Flight Center, the Drop Physics Module (DPM) from the Jet Propulsion Laboratory, and the Surface Tension Driven Convection Experiment (STDCE) from the Lewis Research Center, were delivered to KSC only three years after flight confirmation. This fast-paced development process called for new technical and management approaches to insure that the science objectives of the flight hardware were not compromised. Central to the success of this program was the establishment of highly cooperative working relationships among the NASA Field Centers involved in the mission.

NASA COMMUNICATED THE OBJECTIVES, ACTIVITIES, AND RESULTS OF THE MICROGRAVITY SCIENCE PROGRAM THROUGH AN AGGRESSIVE EDUCATIONAL OUTREACH PROGRAM. The Agency's first ever microgravity science teachers guide, *Microgravity - A Teacher's Guide With Activities*, was developed, published and made available to thousands of secondary-level educators. This guide contained a primer covering the science disciplines supported by the Microgravity Science Program, as well as a dozen different demonstrations designed to be performed in any classroom. In late June and early July, fifteen "Today in Space" NASA Select television productions describing the USML-1 microgravity investigations were developed and aired. A special NASA Education Satellite Teacher Video Conference on Microgravity, accessible to over 10,000 schools across the United States, was broadcast on December 15, 1992.

MICROGRAVITY SCIENCE SPAWNED TECHNOLOGY DEVELOPMENT IN A WIDE RANGE OF DIAGNOSTICS. The Lambda Point Experiment on USMP-1 required an on-orbit temperature measurement and control system capable of being commanded from the ground by the Principal Investigator, in real-time, with an accuracy of one-billionth of a kelvin. This was a hundred times better than possible on Earth. The microgravity science program defined it, designed it, built it and it worked as desired.

NASA CONTINUED TO MOVE AGGRESSIVELY BUT SENSIBLY TOWARD A BROAD CAPABILITY FOR EXPERIMENTATION IN SPACE, LEADING ULTIMATELY TO USE OF SPACE STATION *FREEDOM* AND OTHER ADVANCED CARRIERS. USML-1 also served as a Space Station *Freedom* (SSF) precursor flight, demonstrating the operational concept for the Space Station Furnace Facility (SSFF). The Crystal Growth Facility on USML-1 was used for the required SSFF proof-of-concept five years earlier than originally scheduled. Telescience techniques used to remotely operate experiments on USMP-1 provided an important window to the future for early SSF operations.

NASA'S MICROGRAVITY SCIENCE PROGRAM DEMONSTRATED THE UNITED STATES PREEMINENCE IN MICROGRAVITY SCIENCE, TECHNOLOGY, AND APPLICATIONS DURING 1992.



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APPENDIX: Acronyms and Abbreviations

SECTION 1: **Introduction**

This report describes key elements of the microgravity research program as conducted by the Microgravity Science and Applications Division (MSAD) within the Office of Space Science and Applications (OSSA) during fiscal year (FY) 1992. This NASA funded program supported investigators from the university, industry, and government research communities. This report summarizes the program's goals, the approach taken to achieve those goals, and the resources that were available. It provides a "snapshot" of the Program's status at the end of FY 1992 and reviews highlights and progress in the ground and flight-based research during the year. It also describes four major space missions that flew during FY 1992, the advanced technology development (ATD) activities, and the plans to use the research potential of Space Station Freedom and other advanced carriers.

The MSAD program structure encompassed five research areas:

- 1) Biotechnology, focusing on macromolecular crystal growth as well as cellular response to low stress environments,
- 2) Combustion Science, focusing on processes of ignition, propagation and extinction during combustion in a low-gravity environment,
- 3) Fluid Physics, including aspects of fluid dynamics and transport phenomena affected by the presence of gravity,
- 4) Materials Science, including electronic and photonic materials, glasses and ceramics, and metals and alloys,
- 5) Benchmark Physics, including the study of critical phenomena, low temperature physics and other phenomena where significant advantages exist for studies in a low gravity environment.

Experiments in these areas typically sought to provide a better understanding of gravity-dependent physical phenomena and those phenomena made obscure by the effects of gravity. Results were used to challenge and validate contemporary scientific theories, to identify and describe new physical aspects that are unique to the low gravity environment, and to engender the development of new theories through the acquisition of unexpected and unexplained results.

The commercial microgravity program was conducted by the Commercial Flight Experiments Division within the newly created Office of Advanced Concepts and Technology (OACT). The OACT sought to stimulate and facilitate U.S. industry participation and investment in the commercial development of space. This involved the identification of industrially-oriented research objectives in response to industry goals and an implementation in partnership with suitable academic and government partners. This industrially-oriented research was sponsored by NASA and its industrial and academic partners and included collaboration with some of NASA's basic research programs.

The approaches of OSSA and OACT to the implementation of NASA's complementary microgravity programs are summarized in this report, but accomplishments of the FY 1992 commercial microgravity program are reported elsewhere. This annual report focuses on the microgravity research program as conducted by the Microgravity Science and Applications Division of OSSA.

A complementary document to this annual report is the "Microgravity Science and Applications Program Tasks and Bibliography for FY 1992", NASA Technical Memorandum 4469, March 1993. Detailed information on the research tasks funded by MSAD during FY 1992 are listed and it is an excellent reference for supplementary information to this annual report. Table 1.1 summarizes some of the information in the program task book that may be of interest to the reader.

Table 1.1 FY92 Program Research Task Summary: Overview Information & Statistics

Total Number of Principal Investigators: **144**

Total Number of Publication Citations and Presentation Credits: **559**

Total Number of Patents Cited: **7**

FY 1992 Microgravity Science & Applications Budget: **\$120.8 Million**

Number of U.S. States with Funded Research (including District of Columbia): **32**

Distribution of Microgravity Science and Applications Research Tasks & Types				
Centers	Types of Research:			Center Totals
	Ground	Flight	ATD	
Jet Propulsion Laboratory	13	4	2	19
Johson Space Flight Center	2	1	0	3
Langley Research Center	4	1	1	6
Lewis Research Center	45	19	5	69
Marshall Space Flight Center	19	18	2	39
NASA Headquarters	8	0	0	8
Totals:	91	43	10	144

SECTION 2:

Microgravity Program Goals for 1992

The MSAD Microgravity Research Program during FY 1992 was developed and implemented using an integrated plan that included space science, applications and commercialization objectives. The Program's mission during this period was to:

Obtain new knowledge and increase the understanding of gravity-dependent physical phenomena and those phenomena obscured by the effects of gravity in biological, chemical and physical systems , and, where feasible, to facilitate the application of that knowledge to commercially viable products and processes.

The Microgravity Program goals for FY 1992 were to:

Goal 1: Develop a comprehensive research program in biotechnology, combustion science, fluid dynamics and transport phenomena, materials science, and selected investigations of other gravity-dependent phenomena.

Goal 2: Foster the growth of an interdisciplinary community to conduct the research and to disseminate the results.

Goal 3: Enable the research through the development of suitable experiment apparatus and by choosing the carrier most appropriate for the experiment.

Goal 4: Promote United States commercial involvement and investment for the development of new, commercially viable products, services, and markets resulting from research in the space environment.

Goal 5: Foster international cooperation and coordination in conducting low gravity research of mutual benefit, while maintaining the United States' competitive commercial position.

SECTION 3: Microgravity Program Approach for 1992

NASA's Office of Space Science and Applications and the recently formed Office of Advanced Concepts and Technology had a complementary approach for implementation of the overall NASA microgravity science and applications program. The Microgravity Science and Applications Division focused on basic and applied research to contribute to a fundamental understanding of physical phenomena and to enable technological advances. The Commercial Flight Experiments Division of OACT focused on industrially-oriented research and program development initiatives that encouraged and facilitated participation and investment of U.S. industry in commercial space endeavors.

MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION (MSAD)

The MSAD approach to conducting space research followed the previously established process of starting with new ideas proposed by individuals or teams of investigators in response to discipline specific solicitations. These proposals were then peer reviewed. All selected new ideas underwent a ground-based definition phase to collect data, to confirm the scientific rationale for access to a low-gravity environment, and to focus the research objectives. As a result of this approach, research activities were in various phases of the process throughout the year.

Flight-dependent hypotheses were refined or confirmed and their associated flight objectives validated using ground-based, reduced-gravity facilities. In these facilities, low-gravity test environments of varying durations were available—up to 2.2 seconds in drop towers and drop tubes (the 5-second drop tower was closed for most of FY 1992 for refurbishment), 25 seconds in aircraft, and 15 minutes in suborbital rockets. To support these investigations (as well as those requiring longer periods of reduced gravity) the flight program selected the most cost-effective option from a broad range of hardware and carrier resources.

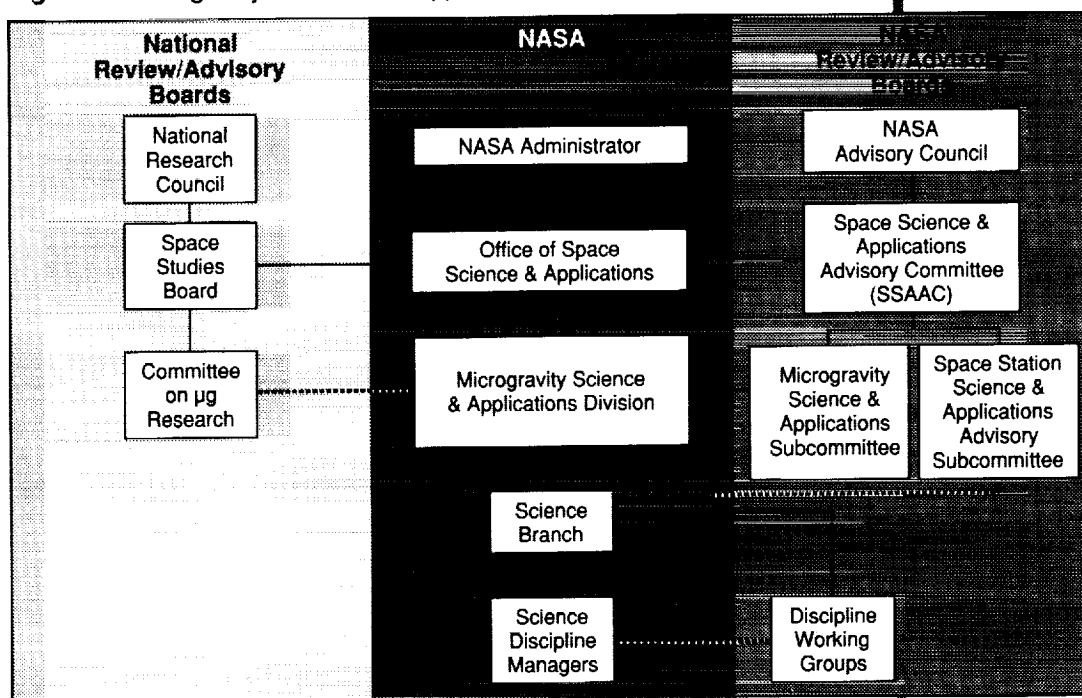
MSAD cooperated with NASA's international partners by establishing and maintaining international working groups with one or more national agencies and through multilateral agreements with individual governments. Typically, NASA would offer to provide access to space while the international partners would offer to provide flight hardware of significant interest to the U.S. science community. The experimental data would then be shared by the participating countries. Also, United States investigations could have international co-investigators. The program has sought to share and maximize the science return while minimizing the total experiment cost.

MSAD continued to support a cooperative program that offered opportunities for U.S. investigators to propose the use of international

hardware. Experience gained through hardware development in one country has been shared to affect future hardware development in another country. Every effort was made to maintain an open exchange while protecting individual rights to designs, data and technologies.

MSAD worked with and received guidance from several advisory and review groups during FY 1992. These groups and their relationships to NASA are shown in Figure 3.1. Program content, plans and priorities were reviewed periodically by the Microgravity Science and Applications Subcommittee. The Space Station Science and Applications Advisory Subcommittee continually reviewed the program with regard to Space Station utilization. Both are subcommittees of the Space Science and Applications Advisory Committee that reviews the activities of the OSSA and, in turn, are represented on the NASA Advisory Council. In addition, MSAD supported a review of NASA technology programs performed by a special National Research Council committee made up of members of the National Academy of Sciences and the National Academy of Engineering. The Committee on Microgravity of the Space Studies Board continued its efforts to define a long-range research strategy for NASA's Microgravity Science Program. This strategy is expected to be released by the National Research Council in FY 1994.

Figure 3.1 Microgravity Science and Applications Review and Advisory Boards



Four Science Discipline Working Groups (DWG) were established in FY 1992 in the areas of Biotechnology, Combustion, Fluids and Transport Phenomena and Materials Science. The DWG were responsible for maintaining an overview of the efforts in the discipline areas, and for providing an annual program assessment. They began the process to recommend discipline refinements and science priorities including an assessment of the strengths and weaknesses of the microgravity research program. The DWG also began to identify the most promising areas for investigation and the most advantageous approaches for experimentation.

MSAD continued an advanced technology program with the objectives of enhancing the capabilities of experimental hardware, overcoming technology-based limitations in its science program, and enabling new types of scientific investigations. In FY 1992, these MSAD technology development efforts continued to be coordinated with the programs of the Office of Advanced Concepts and Technology (OACT) to identify the most cost-effective means of meeting MSAD technology needs.

OFFICE OF ADVANCED CONCEPTS AND TECHNOLOGY (OACT)

During FY 1992, OACT-sponsored Centers for the Commercial Development of Space (CCDS) were the primary mechanism through which industry — in partnership with universities, nonprofit institutes and other government agencies — participated in an industry-driven, commercially oriented microgravity program. A listing of the CCDSs involved in the microgravity program and their affiliation is shown in Table 3.1. OACT provided seed money to develop the CCDSs at universities and nonprofit organizations, which were also supported by industry contributions. The CCDSs formed partnerships with various industries that shared a common interest in focused or applied space research. The amount of such support is a major consideration in OACT approval for the activities. These centers provided an excellent mechanism for combining academic and industrial research to ensure experiments had industrial relevance.

In addition to implementing a space flight activity through a CCDS, industry could also propose directly to OACT to fly commercial development payloads through arrangements such as a Joint Endeavor Agreement (JEA). Such an agreement recognized that some industrial partners may not require or desire the "incubator" support of a CCDS. Other agreements such as the Technical Exchange Agreement (TEA) were intended to facilitate exploration of the knowledge and capability base in research areas of mutual interest to industrial partners and NASA.

Table 3.1 NASA Microgravity Centers for the Commercial Development of Space (CCDS)

Center for Advanced Materials Frank Jellinek, Director	Battelle Columbus Laboratories Columbus, OH
Center for Macromolecular Crystallography Charles Bugg, Director	University of Alabama Birmingham, AL
Consortium for Materials Development in Space Charles Lundquist, Director	University of Alabama Huntsville, AL
Center for Space Processing of Engineering Materials R. A. Overfelt, Director	Vanderbilt University Nashville, TN
Center for Commercial Crystal Growth in Space William Wilcox, Director	Clarkson University Potsdam, NY
Space Vacuum Epitaxy Center Alex Ignatiev, Director	University of Houston Houston, TX
Center for Bioserve Space Technologies Marvin Luttiges, Director	University of Colorado Boulder, CO
Space Automation and Robotics Center (SpARC) Robert Sampson, Director	Environmental Research Institute of Michigan (ERIM) Ann Arbor, MI
Center for Cell Research Wesley Hymer, Director	Pennsylvania State University University Park, PA

SECTION 4:

Microgravity Research for 1992

OVERVIEW

NASA funded a robust microgravity research program in a wide variety of microgravity-related disciplines. Though each research task was designed to yield a deeper understanding of phenomena within a particular scientific discipline, the knowledge gained from research in one field often had interdisciplinary impacts. Investigations sponsored as part of the microgravity science program shared one characteristic; they required reduced or near-zero gravity conditions in order to achieve their objectives.

The overall Microgravity Research Program was conducted through integrated ground-based and flight programs. The primary functions of the ground-based research program during this period were to develop concepts that led to flight experiments; to determine limitations of various terrestrial processing techniques; and to provide analysis and modeling support to the flight program. A successful ground-based research program generally represents a necessary first step toward flight experimentation. In FY 1992, MSAD directly funded a total of 144 microgravity research activities; 101 in the ground-based program and 43 in the flight program.

HIGHLIGHTS OF THE FY 1992 MICROGRAVITY RESEARCH PROGRAM

Highlights of NASA's microgravity research program in FY 1992 are presented below. Research activities are classified into five categories: biotechnology, combustion, fluid physics, materials science, and benchmark physics.

Biotechnology

In 1992, the MSAD biotechnology research program continued to focus on growing crystals of biological molecules of the size and quality appropriate for high resolution x-ray crystallography studies. These studies were directed towards resolving the detailed structures of biologically important molecules as well as improving basic understanding of the protein crystal growth process. Structural biology is a major field of basic biomedical research, and crystallography is the most powerful method for determining the structures of complex biological molecules. The biotechnology program also investigated the characteristics of human cell and tissue growth in the low shear-stress environment provided by the Bioreactor.

With the flight of protein crystal growth experiments on three missions, as well as extensive ground research, 1992 was a particularly active year for this area of research. In particular, the size and high

internal order of Satellite Tobacco Mosaic Virus crystals grown on orbit allowed greatly enhanced structural knowledge to be obtained for this crop virus.

A new imaging plate detector system at the Marshall Space Flight Center (MSFC) has significantly enhanced their structural determination capabilities. The structural determination of human serum albumin, the most abundant protein in the circulatory system, was published in a recent issue of *Nature* and the structures of a number of other albumins have been refined. Comparisons of these structures are revealing a wealth of information regarding the evolution and chemistry of these important macromolecules. Structural investigations on human antibodies expressed against the human immunodeficiency virus type 1 (HIV-1) continued with work on the structure of the monoclonal antibody Fab (3D6) recently appearing in the *Proceedings of the National Academy of Science*. Fundamental research in protein crystallization looked at improving current understanding of the crystal growth process, particularly with regard to the initial step of nucleation. Results of lysozyme experiments indicated that more protein aggregation was occurring, in both under and over-saturated protein solutions, than had previously been believed.

Over the past three years, research with the Bioreactor enabled development of cell cultures that behave more like the three-dimensional tissues of the human body. The cells appeared to recreate the correct three dimensional relationships in the Bioreactor as in human tissues. This work is continuing with test flights of culturing vessels using synthetic particles to model tissues. A recent *Molecular Biology of the Cell* article detailed the results of epithelial cell growth studies. Adenocarcinoma tissue that expressed biochemical markers not seen in standard tissue cultures was also successfully grown. In addition, cooperative research studies using the Bioreactor focused on a wide range of normal and cancerous tissues including breast, ovarian, bladder, prostate, cartilage, and bone. Table 4.1 lists the 6 biotechnology tasks that were directly funded by MSAD in FY 1992 along with the associated principal investigators and affiliated institutions.

Table 4.1 Biotechnology Tasks funded by MSAD in FY 1992

GROUND EXPERIMENTS

Biosynthesis of Cellulose under Microgravity Conditions	Prof. R. Macromano University of Ljubljana
---	--

Crystallographic Studies of Protein

Dr. Daniel C. Carter
NASA Marshall Space Flight Center
Huntsville, AL

Protein Crystal Growth in Low Gravity	Prof. Robert S. Feigel
	Stanford University
	Stanford, CA

3-Dimensional Modeling of Human Colon Tissues	Dr. J. Milburn Jessup
	New England Deaconess Hospital
	Boston, MA

Separation of Chromosome-size DNA Molecules	Prof. Ponzy Lu
	University of Pennsylvania
	Philadelphia, PA

Studies on the Protein Crystal Nucleation Process	Dr. Marc L. Pusey
	NASA Marshall Space Flight Center
	Huntsville, AL

FLIGHT EXPERIMENTS

Protein Crystal Growth in a Microgravity Environment	Prof. Charles E. Bueh
	University of Alabama
	Birmingham, AL

Electrophoretic Separation of Cells and Particles from Rat Pituitary and Rat Spleen	Prof. Wesley C. Hymer
	Penn State University
	University Park, PA

Enhanced Hybridoma Production Using Electrofusion	Prof. David W. Sammons
	University of Arizona
	Tucson, AZ

Electrophoresis Technology	Dr. Robert S. Snyder
	NASA Marshall Space Flight Center
	Huntsville, AL

Macromolecular Crystal Growth Experiments	Dr. Alexander McPherson, Jr.
	University of California
	Riverside, CA

Combustion Science

The objectives of the FY 1992 MSAD research program in combustion were to understand the processes of ignition, propagation and extinction during combustion in a low-gravity environment. This work was directed at both fundamental research and issues of fire safety in space. Investigations focused on studies of the processes of ignition, flame spreading, flame extinction, flame physical characteristics such as size and shape, and soot formation and its role in combustion. Also investigated were air flows and heat and mass transfer phenomena at a combustion site for a variety of materials from fuel vapors, to liquid pools, to paper and metal solids.

The characteristics of smoldering combustion were also studied. An approach was used in the combustion research that included a balance

between theoretical modeling and experiments that made extensive use of the 2.2 second NASA drop tower mentioned in Section 6. The Solid Surface Combustion Experiment (SSCE) was flown on two Space Shuttle flights during 1992. It was designed to determine the mechanism of gas-phase flame spread over solid fuel surfaces in a low-gravity environment. Combustion experiments were also performed on NASA aircraft using parabolic flight trajectories.

In FY 1992, experimental work with gas jet diffusion flames revealed new differences between the spread of flame turbulence in low-gravity and Earth gravity, stimulating keen interest in the scientific community. Experiments using a range of hydrocarbon fuels showed that, in microgravity these disturbances propagated from the base of the flame, while on Earth the disturbances first appear at the flame tip. Work also continued on the numerical modeling of laminar flames. Model predictions correlated well with previous drop tower results.

Several investigations studying the combustion of flammable droplets and sprays continued this year with the design, construction and testing of novel types of reaction apparatus. In addition, analytical studies of the extinction of heptane diffusion flames predicted the extinction diameters of fuel drops.

Testing in normal gravity was the first step in studying the role of buoyant convection in flame spread across liquid pools in 1992. Both the flame character and the flame spread rate were found to be dependent on pool depth for a variety of reaction conditions. Computational models are being developed to explain the ground results and to predict the effects of varying the gravity level. New instrumental techniques were also applied that allowed liquid flow to be observed to the full depth of the pool. Table 4.2 lists the 23 MSAD combustion science tasks funded in FY 1992.

Table 4.2 Combustion Science Tasks funded by MSAD in FY 1992

GROUND EXPERIMENTS

An Experimental and Theoretical Study of
Radiative Extinction of Diffusion Flames

Prof. Arvind Atreya
Michigan State University
East Lansing, MI

Ignition and Combustion of Bulk Metals
in Microgravity

Prof. Melvyn C. Brannan
University of Colorado
Boulder, CO

Modeling of Microgravity Combustion Experiments

Prof. John C. Buckmaster
University of Illinois
Urbana, IL

Gravitational Effects on Premixed Turbulent Flames:	Dr. Robert K. Chel
Studies of the Dynamics of Wrinkled	Lawrence Berkeley Laborat
Laminar Flames in Microgravity	Berkeley, CA

Combustion of Interacting Droplet Arrays In a Microgravity Environment	Dr. Daniel Dietrich Sverdrup Technology Inc., LeRC Brook Park, OH
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Combustion of Electrostatic Sprays of Liquid	Prof. Alessandro Gome
Fuels in Laminar and Turbulent Regimes	Yale Universi
	New Haven, C

Structure and Dynamics of Premixed Flames In Microgravity	Dr. K. Kailasanath Naval Research Laboratory Washington, DC
--	---

Radiative Ignition/Subsequent Flame Spread of Cellulosic Fuels in Microgravity	Dr. Takashi Kashiwa Natl. Institute of Standards & Technology Gaithersburg, M
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Measurements and Modeling of Sooting Turbulent Jet Diffusion Flames Under Normal and Reduced-Gravity Conditions	Prof. Jerry C. Ku Wayne State University Detroit, MI
---	--

Studies of Flame Structure in Microgravity	Prof. Chung K. La
	Princeton Universi
	Princeton, N

A Fundamental Study of the Combustion Synthesis of Ceramic-Metal Composite Materials Under Microgravity Conditions	Prof. John J. Moore Colorado School of Mines Golden, CO
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Combustion Research	Dr. Howard Ros
	NASA Lewis Research Cent
	Cleveland, O

Combustion Experiments in Reduced Gravity with 2-Component Miscible Droplets	Prof. Benjamin Shaw University of California Davis, CA
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Combustion of Solid Fuel in Very Low Speed Oxygen Streams	Prof. James Tie Case Western Reserve University Cleveland, O
--	--

High Pressure Droplet Combustion Studies	Prof. Forman A. Williams University of California, San Diego La Jolla, C
--	--

FLIGHT EXPERIMENTS

Scientific Support for an Orbiter Middeck Experiment on Solid Surface Combustion	Prof. Robert A. Altenkirch Mississippi State Universi Mississippi State, M
---	--

Low-Velocity, Opposed-Flow Flame Spread in a Transport-Controlled, Microgravity Environment	Prof. Robert A. Altenkirch Mississippi State University Mississippi State, MS
--	---

Gas Jet Diffusion Flames (GDF) Experiment	Dr. Yousef Bahado SAIC, Inc. Torrance, CA
--	--

Investigation of Laminar Jet Diffusion Flames in Microgravity: A Paradigm for Soot Processes in Turbulent Flames	Prof. Gerard M. Faeth University of Michigan Ann Arbor, MI
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Fundamental Study of Smoldering Combustion in Microgravity	Prof. A. Carlos Fernandez-Pello University of California Berkeley, CA
---	--

Premixed Laminar and Turbulent Flames at Microgravity	Prof. Paul D. Ronney Princeton University Princeton, NJ
--	--

Flame Spread Across Liquids	Dr. Howard Ro NASA Lewis Research Center Cleveland, OH
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Scientific Support for a Space Shuttle Droplet Burning Experiment	Prof. Forman A. Williams University of California, San Diego La Jolla, CA
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Fluid Physics

The objective of the microgravity fluid physics program during FY 1992 was to conduct a comprehensive research program on fluid dynamics and transport phenomena where fundamental behavior is limited or affected by the presence of gravity, and where low-gravity experiments allow insight into that behavior. For example, a low-gravity environment results in greatly reduced density-driven convection flows and allows the study of other forms of convection such as flows driven by surface tension gradients, magneto/electrodynamics, or other interfacial phenomena. Investigations of these phenomena result in the basic scientific and practical knowledge needed to design effective and reliable space-based systems and facilities that rely on fluid processes.

Another objective of the fluid physics program was to assist other MSAD disciplines, such as materials science or combustion science, by developing an understanding of those gravity-dependent fluid phenomena that could effect the success of their programs. Over the last year, much of this work was focused on the development of the numerical modeling necessary to link the complex variables affecting the various dynamic fluid systems being studied. Work performed with thermal convection models of strongly rotating liquid spheres, which varies with the latitude of the sphere, can be applied to the differential rotation of stars and gas giants. Scaling of the developed model yielded results consistent with the solar pulsation cycle and with Voyager observations of Jupiter's jet streams.

A critical point experiment looking at density variations and time scales was successfully flown in 1992, logging 60 hours of imaging interferometric fringes. The critical point is the pressure and temperature combination at which the distinction between the liquid and gas states of a fluid ceases to exist. Preliminary results of the flight experiment agreed with theoretical predictions regarding heat diffusion rates near the critical point. This information will be used to support another flight in 1994.

The performance of prototype hardware for a pool boiling experiment flown aboard the Space Shuttle was judged to be near perfect. The resulting data showed that pool boiling in reduced gravity is a transient process and not a steady periodic one. To support boiling studies in thin liquid films, a drop tower test rig was designed and assembled at Lewis Research Center to look at the interaction between fluid dynamics, heat transfer and buoyancy. Table 4.3 lists the 29 MSAD Fluid Physics tasks funded during FY 1992.

Table 4.3 Fluid Physics Tasks funded by MSAD in FY 1992

GROUND EXPERIMENTS

Reactive Fluids Experiment: Chemical Vapor Deposition	Dr. Ivan O. Clar NASA Langley Research Center Hampton, VA
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Fluid Interface Behavior Under Low- and Reduced-Gravity Conditions	Prof. Paul Concus University of California Berkeley, CA
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Convection and Morphological Stability during Directional Solidification	Dr. Sam R. Cone Natl. Institute of Standards & Technology Gaithersburg, MD
--	--

Drop Microphysics	Prof. Robert H. Davis University of Colorado Boulder, CO
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Bubble-In-Liquid Mass Transport Phenomena in a Reduced Gravity Environment	Prof. Kenneth J. DeWitt University of Toledo Toledo, OH
--	---

Studies of Two Phase Flow under Microgravity	Prof. A. E. Dukler University of Houston Houston, TX
--	--

Theoretical Influence of Microgravity on Critical Fluid Measurements	Prof. Richard A. Ferro University of Maryland College Park, MD
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Molecular Dynamics of Fluid-Solid Systems	Prof. Joel Koplik City College of New York New York, NY
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Fluid Dynamics and Solidification of Metallic Melts (FDSMM)	Prof. Jean N. Kosbar University of Colorado Boulder, CO
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Nonlinear Drop Dynamics and Chaotic Phenomena	Prof. L. Gary Leal University of California Santa Barbara, CA
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Pool Boiling Experiment	Prof. Herman Mahle University of Michigan Ann Arbor, MI
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Thermocapillary Convection	Prof. G. Paul Neitzel Georgia Institute of Technology Atlanta, GA
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Industrial Processes	Prof. Simon Ostrach Case Western Reserve University Cleveland, OH
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Containerless Capillary Wave Turbulence	Dr. Seth J. Putterman University of California Los Angeles, CA
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Transport Processes Research	Jack Salzman NASA Lewis Research Center Cleveland, OH
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Dielectric/Electrohydrodynamic Properties	Prof. Dudley A. Saville Princeton University Princeton, NJ
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The Roles of Fluid Motion and Other Transport Phenomena in the Morphology of Materials	Dr. Dudley A. Saville Princeton University Princeton, NJ
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Capillary Containment of Liquids in a Microgravity Environment	Prof. Paul H. Steen Cornell University Ithaca, NY
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Mechanics of Granular Materials	Prof. Stein Shtrikman University of Colorado Boulder, CO
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Computational Studies of Drop Collision and Coalescence	Prof. Gretar Tryggvason University of Michigan Ann Arbor, MI
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Theoretical Studies of Residual Accelerations in a Microgravity Environment; Stochastic Formulation of Fluid Flow Phenomena	Prof. Jorge Vinals Florida State University Tallahassee, FL
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Studies of the Dynamics of Charged Free Drops	Prof. Taylor G. Wang Vanderbilt University Nashville, TN
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FLIGHT EXPERIMENTS

Surface Controlled Phenomena	Prof. Robert E. Apfel Yale University New Haven, CT
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Kinetics of Diffusional Droplet Growth

Dr. Donald O. Frazier
NASA Marshall Space Flight Center
Huntsville, AL

Geophysical Fluid Flow Cell

Prof. John E. Hart
University of Colorado
Boulder, CO

Interfacial Phenomena in Multilayered Fluid Systems

Prof. Jean N. Koster
University of Colorado
Boulder, CO

Surface Tension Driven Convection Experiment

Prof. Simon Ostrach
Case Western Reserve University
Cleveland, OH

Thermocapillary Migration and Interactions of Bubbles and Drops

Prof. Shankar Subramanian
Clarkson University
Potsdam, NY

Droplet Dynamics Investigation

Prof. Taylor G. Walton
Vanderbilt University
Nashville, TN

Materials Science

The goal of the microgravity materials science program during FY 1992 was to use the unique characteristics of the space environment to better understand the processes by which materials are produced as well as their properties. Of particular interest was understanding the role of gravity-driven convection in the processing of electronic and photonic materials, metals, alloys, composites, glasses, ceramics, and polymers. Potential industrially-oriented benefits of the materials science program include new materials capable of being produced in the space environment or better understanding of material processes leading to improved process control strategies on Earth.

In FY 1992, the program was characterized by a balance of theoretical studies, fundamental research, and applications-oriented experiments. These investigations were conducted using space-qualified scientific hardware provided by NASA and other cooperating international space agencies. This hardware was used in a variety of configurations ranging from the interactive systems inside the Spacelab module to the automated systems in the Cargo Bay of the Space Shuttle. The ground-based program complemented the flight activity by focusing on necessary numerical and analytical modeling, by conducting exploratory research, and by providing a base in which potential flight research ideas could mature.

The materials science research program involved a wide spectrum of studies that looked at various growth methods, apparatus, and growth conditions, such as the interaction of heat and mass transfers, melt flows, and interface morphologies. Work was also performed on the development of novel measurement techniques suitable for the extreme conditions under which the various materials of interest are produced. For example, directional solidification crystal growth is a temperature-controlled process and therefore the measurement and control of temperature within the growth ampoule is of paramount importance. Therefore, work was performed on the development of instrumented calibration samples, temperature probe placement, and evaluation of various temperature probes to determine which type had the best accuracy and stability without adding undue disturbance to the measurement.

Much of the materials research on metals and alloys in FY 1992 was on solidification zone studies and containerless processing. The results of solidification experiments aboard IML-1 continue to yield a great deal of information on the role that buoyancy plays in the growth of metals from a melt, while separate ground studies have determined that the flow in the upper part of the solidification zone is driven by convection in the all-liquid region. Containerless processing involves the use of levitated samples in order to prevent the solidification process from being affected by contact with container walls. A breakthrough was made in high-temperature electrostatic levitation technology in 1992 and the instrument capabilities were verified with various high density alloys. A patent application was submitted for this instrument. Aero-acoustic and microwave levitators were also used in material studies, including work on glass formation, fluid motion and the liquid-optical properties of a levitated calcia-gallia-silica system.

Electronic materials, including semiconductors and gamma ray detectors, were grown in several experiments performed on orbit in FY 1992. Initial analysis of the two samples of cadmium zinc telluride successfully flown aboard USML-1 indicated the presence of unexpected, and potentially significant, thermal and gravitational asymmetry throughout the steady-state growth period. Drop tower experiments were performed in order to study the containerless solidification of yttrium barium superconducting compounds. Table 4.4 lists the 20 flight and 43 ground-based MSAD Materials Science tasks funded in FY 1992.

Table 4.4 Materials Science Tasks funded by MSAD in FY 1992

GROUND EXPERIMENTS

METALS AND ALLOYS

**Microwave Materials Processing
in Microgravity**

Dr. Martin B. Barmatz
Jet Propulsion Laboratory
Pasadena, CA

**Studies of Containerless Processing of
Selected NB-based Alloys**

Prof. Robert J. Bayuzick
Vanderbilt University
Nashville, TN

**Dynamic Thermophysical Measurements
in Microgravity**

Dr. Ared Cezairliyan
Natl. Institute of Standards & Technology
Gaithersburg, MD

**The Dynamics of Disorder-Order Transitions
in Hard Sphere Colloidal Dispersions**

Prof. Paul M. Chaikin
Princeton University
Princeton, NJ

**Modeling Directional Solidification in
Furnaces/Processes in the Microgravity Materials
Science Laboratory**

Dr. Arnon Chait
NASA Lewis Research Center
Cleveland, OH

**Fluid Mechanics of Directional Solidification
at Reduced Gravity**

Prof. Chuan F. Chou
University of Arizona
Tucson, AZ

Modeling of Coalescence

Prof. Robert H. Davis
University of Colorado
Boulder, CO

Theory of Solidification

Prof. Stephen H. Davis
Northwestern University
Evanston, IL

**Evaluation of Microstructural Development
in Undercooled Alloys**

Prof. Richard N. Grugel
Vanderbilt University
Nashville, TN

**NonContact Thermal, Physical Property
Measurement of Multiphase Systems**

Prof. Robert H. Haug
Rice University
Houston, TX

Fluid Flow During Alloy Solidification

Prof. Angus Hellawell
Michigan Technological University
Houghton, MI

**Containerless Processing of Oxide
Superconductors**

Prof. William H. Hofmeier
Vanderbilt University
Nashville, TN

**Modeling/Experimental Studies of
Droplet Pushing in Miscibility-Gap Alloy
Solidification Under Low-g Conditions**

Prof. William B. Krantz
University of Colorado
Boulder, CO

Containerless Property Measurement of High Temperature Liquids

Dr. Shankar Krishn
Intersonics, II
Northbrook,

Containerless Processing for Controlled Solidification Microstructures

Prof. John H. Perepezko
University of Wisconsin
Madison, WI

The Role of Gravity on Macrosegregation in Alloys

Prof. David R. Poir
University of Arizona
Tucson, AZ

Electrostatic Containerless Processing

Dr. Won-Kyu K. Rhim
Jet Propulsion Laboratory
Pasadena, CA

Crystal Nucleation, Hydrostatic Tension & Diffusion in Metal Melts

Prof. Frans A. Spaep
Harvard University
Cambridge, MA

Levitation Undercooling, Nucleation

Dr. Eugene H. Trinh
Jet Propulsion Laboratory
Pasadena, CA

Coarsening of Solid-Liquid Mixtures

Prof. Peter W. Voorhees
Northwestern University
Evanston, IL

Influence of Convection of Microstructure

Prof. William R. Wilcox
Clarkson University
Potsdam, NY

ELECTRONIC MATERIALS

Growth of Zinc Selenide Single Crystals

Prof. Elmer E. Anders
University of Alabama
Huntsville, AL

Memory Effects in the Organometallic Chemical Beam Epitaxy of Compound Semiconductors

Prof. Klaus J. Bachmann
North Carolina State University
Raleigh, NC

Fluid Mechanics and Mass Transfer in Melt Crystal Growth: Macro- and Micro-scale Analysis of Controlled Solidification

Prof. Robert A. Brown
Massachusetts Institute of Technology
Cambridge, MA

Modeling Internal Radiative Transport in Crystal Growth Process

Prof. Jeffrey J. Derby
University of Minnesota
Minneapolis, MN

Growth of Nonlinear Optical Thin Films/ Vapor Processes

Dr. Donald O. Frazier
NASA Marshall Space Flight Center
Huntsville, AL

Growth of Nonlinear Optical Crystals by Melt Processes

Dr. Donald O. Frazier
NASA Marshall Space Flight Center
Huntsville, AL

Electronic Materials	Thomas Glasgow
	NASA Lewis Research Center
	Cleveland, OH

Microgravity Materials Science Laboratory	Thomas K. Glasgow
	NASA Lewis Research Center
	Cleveland, OH

Growth of Organic Single Crystals by Two Modified Floating-Zone Processes	Prof. Sindo Kou
	University of Wisconsin
	Madison, WI

Process Modeling for Materials Preparation	Prof. Franz Rosenberger
	University of Alabama
	Huntsville, AL

Theory of Materials Growth in Space: The Liquid-Solid Interface	Dr. Arden Sher
	SRI International
	Menlo Park, CA

Growth Kinetics of Physical Vapor Transport Properties: Crystal Growth	Dr. N. B. Singh
	Westinghouse Electric Corporation
	Pittsburgh, PA

Vapor Crystal Growth of Electro-optical Materials	Dr. Frank R. Szofron
	NASA Marshall Space Flight Center
	Huntsville, AL

Modeling Directional Solidification	Prof. William R. Wilcox
	Clarkson University
	Potsdam, NY

Crystal Growth of Device Quality GaAs In Space	Prof. Augustus F. W. Wilson
	Massachusetts Institute of Technology
	Cambridge, MA

GLASSES AND CERAMICS

Glass Formation and Nucleation in Microgravity: Containerless-Processed, Inviscid Silicate/ Oxide Melts, Ground-Based Studies	Prof. Reid F. Cooper
	University of Wisconsin
	Madison, WI

Advanced Photonic Materials Produced by Containerless Processing	Prof. Delbert E. Day
	University of Missouri
	Rolla, MO

Kinetics of Phase Transformations in Glass Forming	Prof. Kenneth F. Kelton
	Washington University at St. Louis
	St. Louis, MO

Chemical Vapor Deposition of High-to- Superconducting Films in a Microgravity Environment	Prof. Moises Levy
	University of Wisconsin
	Milwaukee, WI

Kinetics of Phase Transformation in Glass Forming	Prof. Chandra S. Ray
	University of Missouri, Rolla
	Rolla, MO

Containerless Liquid Phase Processing of Ceramic Materials

Dr. J. K. Richard Weber
Intersonics, Inc.
Northbrook, IL

Glass Forming Ability and Crystallization of Glass

Prof. Michael C. Weinberg
University of Arizona
Tucson, AZ

FLIGHT EXPERIMENTS METALS AND ALLOYS

In-Situ Monitoring of Crystal Growth Using MEPHISTO

Prof. G.J. Abbaschian
University of Florida
Gainesville, FL

Effects on Nucleation by Containerless Processing

Prof. Robert J. Bayuzick
Vanderbilt University
Nashville, TN

Alloy Undercooling Experiments in Microgravity Environment

Prof. Merton C. Flemming
Massachusetts Institute of Technology
Cambridge, MA

Gravitational Role in Liquid-Phase Sintering

Prof. Randall M. German
Pennsylvania State University
University Park, PA

Isothermal Dendritic Growth Experiment

Prof. Martin E. Glicksman
Rensselaer Polytechnic Institute
Troy, NY

Thermophysical Properties of Metallic Glasses and Undercooled Alloys

Prof. William L. Johnson
California Institute of Technology
Pasadena, CA

Casting and Solidification Technology

Prof. Mary Helen McCay
University of Tennessee Space Institute
Tullahoma, TN

Measurement of Viscosity and Surface Tension in Undercooled Melts

Prof. Julian Szekely
Massachusetts Institute of Technology
Cambridge, MA

ELECTRONIC MATERIALS

Directional Solidification of Cadmium Telluride

Prof. Frederick M. Caruso
Clarkson College
Potsdam, NY

GaAs Crystal Growth Experiment

Dr. Brian Ditchek
GTE Laboratories, Inc.
Waltham, MA

Compound Semiconductor Growth in Low-g Environment

Dr. Archibald L. Friedman
NASA Langley Research Center
Hampton, VA

**A Study of Solution Crystal Growth
In Low-g**

Prof. Ravindra B. Lal
Alabama A&M University
Normal, AL

**Orbital Processing of High Quality Cadmium
Telluride Compound Semiconductors**

Dr. David J. La
Grumman Corporate Resear
Bethpage,

**Crystal Growth of II-IV Semiconducting
Alloys by Directional Solidification**

Dr. Sandor L. Lehoczy
NASA Marshall Space Flight Center
MSFC, AL

**The Study of Dopant Segregation Behavior
During the Growth of GaAs in Microgravity**

Prof. David H. Matthie
Case Western Reserve Unive
Cleveland,

Cadmium Telluride Microgravity Growth

Dr. Ratnakar R. Neurgaonkar
Rockwell International
Thousand Oaks, CA

**Double Diffusive Convection during Growth
of Lead Bromide Crystals**

Dr. N.B. Sin
Westinghouse Electric Corpora
Pittsburgh,

Vapor Crystal Growth Studies

Dr. Lodewijk van den Berg
EG&G
Goleta, CA

**Vapor Transport Crystal Growth of
Mercury-Cadmium Telluride in Microgravity**

Prof. Heribert Wiedem
Rensselaer Polytechnic Inst
Troy,

GLASSES AND CERAMICS

**Measurement of Liquid-Liquid
Interfacial Tension**

Prof. Michael C. Weinberg
University of Arizona
Tucson, AZ

Benchmark Physics

The objective of the MSAD benchmark physics program during 1992 was to provide the opportunity to test fundamental scientific theories to a level of accuracy not possible in the one gravity environment on Earth. The research was directed at achieving measurements at new levels of resolution that would serve as standards for years to come. The benchmark physics program encompasses research on transient and equilibrium critical phenomena, as well as other thermophysical measurements of interest in condensed matter physics.

Particularly noteworthy for FY 1992 was the performance of an extremely successful condensed matter physics experiment aboard the

first United States Microgravity Payload that flew in October 1992. A high-resolution thermometer based on superconducting technology and a multilayer thermal control system were used to test phase transition theories by performing heat capacity measurements near the lambda point of liquid helium (2.177 kelvin). The experiment operated flawlessly with close to 100 high resolution heat-capacity measurement sweeps performed across the helium lambda point. Additional data resulted in important new information about thermal conductivity in a temperature region totally inaccessible on Earth. This experiment also demonstrated the utility of investigators on the ground being able to directly interact with the flight experiment. Through the use of tele-science, more than 5000 commands were successfully sent up to the flight experiment. Table 4.5 lists the 8 benchmark physics tasks funded by MSAD in FY 1992.

Table 4.5 Benchmark Physics Tasks funded by MSAD in FY 1992

GROUND EXPERIMENTS

Determination of the Correlation Length in Helium II in a Microgravity Environment	Prof. Russel Donnelly University of Oregon Eugene, OR
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Space Technology Experiments Platform (STEP)	Prof. C. W. Francis Everitt Stanford University Stanford, CA
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Critical Transport Phenomena in Fluid Helium Under Low Gravity	Prof. Horst Meyer Duke University Durham, NC
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Precise Viscosity Measurements Very Close to Critical Points	Dr. Michael R. Moldover Natl. Institute of Standards & Technology Gaithersburg, MD
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Studies in Electrohydrodynamics	Prof. Dudley A. Saville Princeton University Princeton, NJ
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FLIGHT EXPERIMENTS

Modeling of Coalescence	Prof. Robert W. Gammon University of Maryland College Park, MD
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Heat Capacity Measurements Near the Lambda Point of Helium	Prof. John A. Lipa Stanford University Stanford, CA
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Critical Fluid Thermal Equilibration	Dr. Allen Wilkins NASA Lewis Research Center Cleveland, OH
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SECTION 5:

Microgravity Program Missions During 1992

MICROGRAVITY MISSIONS FLOWN DURING 1992

Fiscal year 1992 was extremely productive for microgravity flight investigations. The extensive ground research program was maintained and three major microgravity science Shuttle flights were conducted, while preparation for a fourth in early FY 93 continued. The Spacelab-based International Microgravity Laboratory (IML-1) flew in January 1992 and the United States Microgravity Laboratory (USML-1) flew in June 1992. MSAD personnel participated in the Spacelab J (SL-J) mission that was dedicated to microgravity and life sciences and flew in September 1992. The United States Microgravity Payload (USMP-1), a Shuttle Cargo Bay mission, flew in October 1992. The IML-1 and USML-1 missions, preliminary research results, and USMP-1 mission objectives are discussed in more detail in the following sections.

First International Microgravity Laboratory (IML-1)

The first of a planned series of NASA sponsored, International Microgravity Laboratory (IML) missions dedicated to fundamental materials and life science research was flown on STS-42 from January 22, 1992 to January 30, 1992. With IML-1, NASA continued its 30-year tradition of sponsoring cooperative space ventures with other countries. The 14-nation European Space Agency (ESA), the Canadian Space Agency (CSA), the French National Center for Space Studies (CNES), the German Space Agency and the German Aerospace Research Establishment (DARA/DLR), and the National Space Development Agency of Japan (NASDA) were NASA's partners in developing flight hardware and experiments for IML-1 and future IML missions. IML-1 used the ESA-developed Spacelab that was installed into the Shuttle payload bay and provided a fully-equipped laboratory environment for microgravity experiments for eight days. This allowed the IML-1 scientists to monitor experiments, change experimental conditions, and refine their investigations based on results. NASA provided mission management, payload integration, and Shuttle transportation to and from orbit. Other space agencies provided hardware of significant interest to the U.S. science community, which was used by their own and NASA scientists. Joint use of internationally developed flight hardware helped to reduce the cost of space experimentation for each agency. Scientific return was amplified by sharing of experimental data and samples among IML-1 investigators.

Half of the IML-1 materials science experiments had flown on previous missions. The reflight opportunity gave scientists a chance to build upon previous results and apply lessons learned to improve experimental techniques. Experimental hardware that flew on IML-1 are listed in Table 5.1.

Table 5.1 IML-1 Experimental Hardware and Developer

Hardware	Developer
Critical Point Facility (CPF)	ESA
Cryostat	DLR
Fluids Experiment System/Vapor Crystal Growth System (FES/VCGS)	NASA
Protein Crystal Growth (PCG)	NASA
Refrigerator/Incubator Module	NASA
Space Acceleration Measurement System (SAMS)	NASA
Mercury Iodide Crystal Growth (MICG)	CNRS
Organic Crystal Growth Facility (OCGF)	NASDA

Preliminary IML-1 science results were presented at the 90-Day Report (Washington, D.C., May 7-8, 1992), an Investigators Working Group meeting (Frascati, Italy, June 16-17, 1992), and in a special session of the Committee on Space Research during the World Space Congress in Washington, D.C. from August 28 through September 5, 1992. A one-year review of IML-1 science results will be held in New Orleans on April 6-9, 1993.

At the end of FY 1992, data obtained from the IML-1 experiments continued to be analyzed and some preliminary results were reported. One such investigation is the Casting and Solidification Technology (CAST) experiment. A better understanding of the casting and solidification processes may lead to development of advanced alloys with improved properties, such as increased strength and durability. When metal alloys solidify, crystal branches, called dendrites, form to create a grain structure that determines some of the alloy's properties. These properties include superconductivity, immiscibility, mechanical strength and corrosion resistance. These properties were expected to be affected, and possibly improved by processing in a low gravity environment where convection flows are minimized.

Experiments were designed to determine the influence of gravity on fluid flow and nucleation during alloy casting and to study solidification and coarsening of dendrite arms and their subsequent influence on the grain structure of alloys. A total of 11 experimental runs were conducted using three different thermal gradients and four growth rates

(i.e., cooling rates). Preliminary results indicated the time to reach steady state growth was much less in microgravity and the growth rates were 50% higher than in the 1-g environment on Earth. It also appears that the number of grains formed in the alloy were much less than observed on Earth. In addition, these growth characteristics were predicted by existing analytical models.

In another investigation, a NASA scientist used the German Cryostat apparatus to grow protein crystals by the liquid-liquid diffusion method and compared the resulting crystals with those grown by the vapor diffusion method in the Protein Crystal Growth (PCG) apparatus. Crystals were grown of canavalin, a major source of food protein in legumes; catalase, a beef liver protein; and satellite tobacco mosaic virus (STMV), a source of plant disease. Because of the multiple crystal forms these compounds can take, the various conditions under which they can be crystallized, and the detailed knowledge available on them, they provide ideal model systems for examining the detailed effects and benefits of growing crystals in space.

Crystals were grown in virtually every trial, but the characteristics of the crystals were highly dependent on the crystallization technique employed and the temperature history of the sample. In general, very good results, based on visual inspection of the crystals, were obtained in both PCG and Cryostat instruments. Unusually impressive results were achieved for STMV crystals grown in the Cryostat instrument. The crystals were more than 10-fold greater in total volume than any STMV crystals previously grown in the laboratory. The X-ray diffraction data are substantially improved over Earth-based observations resulting in a resolution improvement of 1.8 Å over the prior 2.3 Å (an angstrom (Å) equals one ten billionth of a meter). These and other observations indicate growth of macromolecular (protein, nucleic acid, and virus) crystals is influenced by the presence or absence of gravity and that low gravity provides a more favorable environment to produce these crystals. These results were discussed extensively in a recent Protein Science article ("Macromolecular crystal growth experiments on IML-1", vol. 1, No. 10, pp 1254-1268, October 1992).

First United States Microgravity Laboratory (USML-1)

The first United States Microgravity (USML-1) mission was launched on June 25, 1992 on STS-50 and returned July 9, 1992, for a total of 14 days, the longest Shuttle flight to date. This Spacelab-based mission was an important step in a long-term commitment to build a vital microgravity program involving government, academic, and industrial researchers. Thirty-one investigations comprised the payload of USML-1 and covered five basic areas: fluid dynamics, material science, com-

bustion science, biological science and technology demonstrations.

An important aspect of the long term microgravity program continued to be reuse of flight hardware for repeated flights and multiple experiments. There were three facilities or instruments that flew previously on IML-1 or on earlier flights. These include the Protein Crystal Growth (PCG) facility, a Space Acceleration Measurement System (SAMS) on its fourth flight, and the Solid Surface Combustion Experiment (SSCE) also on its fourth flight. Four new experiment facilities flew on USML-1. They were developed to support identified science issues and in response to the 1987 report of NASA's Microgravity Materials Science Assessment Task Force. The resulting hardware was designed for both multiple users and multiple flights and is listed in Table 5.2.

Table 5.2 New Microgravity Science Facilities and Instruments on USML-1

Hardware	Developer
Crystal Growth Furnace (CGF)	MSFC
Glovebox	ESA
Surface Tension Driven Convection Experiment (STDCE) apparatus	LeRC
Drop Physics Module (DPM)	JPL

The Crystal Growth Furnace housed four investigations. It was used to grow high-quality semiconductor and infrared-detector crystals, using both directional solidification and vapor growth techniques. The Glovebox allowed "hands-on" manipulation of experiments while isolating the crew from the liquids, gases, or solids involved. The Surface Tension Driven Convection Experiment apparatus was used to conduct studies of fluid mechanics and heat transfer in low-gravity. The Drop Physics Module used sound waves (acoustic force) to position and manipulate samples for three investigations into the physical and chemical properties and dynamics of liquid drops.

Data from the various experiments performed on USML-1 continue to be analyzed and results are just emerging. For example, three "firsts" were demonstrated by the CGF; 1) use of uplinked software commands (directed by the investigators in response to downlinked data) to control the experiments, 2) automatic exchange of samples in the Integrated Furnace Experiment Assembly, and 3) manual exchange of samples using the flexible glovebox. This proved a concept planned for use in processing on Space Station Freedom, five years in advance of the required proof-of concept demonstration.

The Surface Tension Driven Convection Experiment (STDCE) apparatus was used to study thermocapillary flows (fluid motions generated by temperature variations along the free surface of liquids). Preliminary data seemed to be in agreement with analytic model predictions. The Drop Physics Module (DPM) was dedicated to the detailed study of the dynamics of drops in microgravity: equilibrium shapes, dynamics of fluid flows within a drop, and stable and chaotic drop behavior. It also demonstrated the technique of containerless processing. Some difficulties arose in the operation of the DPM associated with stabilization of an acoustically levitated drop. Results are undergoing analysis. The Protein Crystal Growth (PCG) experiments grew crystals of various proteins under different conditions for studying crystal growth kinetics and the means under which fluid disturbances cause defects in crystals.

In the continuing spirit of international cooperation, the European Space Agency-provided Spacelab Glovebox was used by twenty-four NASA investigators to perform sixteen different experiments. The Glovebox offered an additional capability to test and develop science procedures and technologies in microgravity. It enabled crew members to handle, transfer and otherwise manipulate materials in ways that have been impractical in an open Spacelab. The facility had an enclosed compartment that offered a contained working area to minimize contamination and was also equipped with photographic equipment to provide a visual record of experiment operations. The investigators reported that the Glovebox was an invaluable resource with which to perform microgravity experiments in a manner similar to those performed in ground-based laboratories.

Spacelab J (SL-J)

The Spacelab J (SL-J) mission was dedicated to microgravity and life science experiments and flew on STS-47 from September 12, 1992 through September 20, 1992. For the National Space Development Agency of Japan (NASDA), SL-J provided an opportunity to conduct research in space using resources procured by Japan through reimbursement to NASA. SL-J was the first shared Space Shuttle mission between the U.S. and Japan and was the most ambitious scientific venture between the two countries to date. For NASA, SL-J was another opportunity to conduct low-gravity research in the broad disciplines of microgravity and life sciences. For both agencies, participation in this flight was an important step to strengthening ties internationally.

NASDA's First Materials Processing Test (FMPT) science payload consisted of 34 materials and life science experiments; 22 in materials processing and 12 life science investigations. Materials processing re-

search concentrated on materials science and fluid mechanics, while the life science experiments covered six areas of research that included human physiology, cell biology and radiation biology. The results of this mission are being evaluated.

First United States Microgravity Payload (USMP-1)

The first United States Microgravity Payload (USMP-1) flew on STS-52 from October 22, 1992 through November 1, 1992. Actually an FY 1993 mission, the USMP-1 initiated a series of microgravity missions providing access to space through use of a Shuttle Cargo Bay carrier comprised of two Mission Peculiar Equipment Support Structures (MPESS). USMP-1 was dedicated to experiments designed to study the fundamental behavior of fluid and metallurgical processes at critical phases difficult to observe in ground-based experiments. The Lambda-Point Experiment used microgravity to test the theory of co-operative (second order) phase transition using super-cooled helium and a superconducting-based thermometer with a temperature resolution of better than one billionth of a degree. The French MEPHISTO experiment was developed to study the behavior of metals and semi-conductors during solidification from a molten state. Astronauts were not needed to tend these experiments as both were designed to provide for extensive use of telescience technology to optimize the science return. During the mission, over 5000 commands were sent by the science investigators on the ground directly to their instruments on orbit in an interactive manner. In addition, SAMS provided the first near-real time acceleration data downlink used by investigators to better understand their results.

SECTION 6:
MSAD
Technology,
Hardware and
Education
Outreach
Programs

Flight experience with the available hardware inventory has shown that a front-end investment in technology specific to the microgravity program is essential. To that end, MSAD funded research activities that sought to create or refine equipment that would enhance the scientific fidelity and quality of future microgravity flight experiments. Technology development not specifically on the critical path of any particular flight project, but needed for future projects, continued to be funded through the Advanced Technology Development (ATD) program within the flight program budget element. Other technology development activities were conducted in direct support of on-going or proposed flight experiments, and were funded either directly by or in concert with those flight projects, or from the ground-based program. MSAD also sponsored the development of systems to characterize the reduced-gravity environment of space experiments.

Development and use of flight hardware aboard the Space Shuttle was a major MSAD activity for FY 1992. This hardware was designed for reuse on multiple Shuttle missions to optimize the possible scientific return for a particular hardware investment. Work on six multiuser facilities for use aboard Space Station Freedom continued throughout FY 1992. MSAD also continued an active educational outreach program directed towards the general public, students, and teachers.

SPACE ACCELERATION MEASUREMENT SYSTEM

The objective of the Space Acceleration Measurement System (SAMS) is to provide an acceleration measurement and recording instrument capable of serving a wide variety of space experiments. The apparatus was designed to measure and record the acceleration environment in the Space Shuttle Middeck and cargo bay, and in Spacelab at lower frequencies and longer durations than had been previously achieved. The first SAMS systems were flown in June and August 1991, and again on IML-1, USML-1, SL-J, and USMP-1 in January, June, September, and October 1992, respectively. Development of this capability responds to a 1988 National Academy of Sciences recommendation that spacecraft gravity and vibration levels be precisely measured and characterized on spacecraft carrying chemistry and physics experiments. The data from SAMS is published by the Acceleration Characterization and Analysis Project after every flight.

ADVANCED TECHNOLOGY DEVELOPMENT PROGRAM

The Advanced Technology Development program continued to fund technology research and development tasks of particular relevance to the microgravity research program. Table 6.1 lists the ATD tasks

funded by MSAD in FY 1992 and a brief discussion of each task follows. In addition, technology development maturity was reached on various sensors and were transferred to specific MSAD ground based and flight programs. Following a formal solicitation process, three new ATD tasks were selected for initiation in FY 1993. They include a microsensor-based microgravity accelerometer technology development, combustion diagnostics development, and multi-variable furnace control technology investigation.

Non-Contact Temperature Measurements

A variety of non-contact techniques continue to be developed to accurately sense small temperature changes in high temperature furnace applications. In 1992, continued studies have been made using a Division of Amplitude Polar pyrometer. An additional temperature sensing technique was conceptualized, which will be developed in the coming year. Applications include better high temperature measurement and data acquisition capability for material processing studies.

Microwave Furnace Development

Focused energy from various microwave sources has been used to conduct material melt and re-solidification studies. Various energy level studies conducted on a selected group of materials has resulted in successful melting of the specimens. Development of furnace microwave tuning techniques was also begun. As a result of this novel furnace technology, an entirely new approach to furnace processing techniques may occur.

Ultrasonic Interface Measurements of Crystal Growth

Progress was made in non-contact sensing and shape quantification of the solid/liquid interface of high temperature crystal growth processes. In FY 1992, the ability to transmit and receive ultrasonic pulses from a high temperature sample was successfully demonstrated. Refinements to this pulse-echo technique continue and will provide the potential for a real-time feedback measurement to control a crystal growth process.

Microgravity Fluids and Combustion Diagnostics

Emphasis has been added, in FY 1992, to increasing the development of a series of improved measurement techniques applicable to microgravity combustion science. Improved data accuracy acquisition were of particular interest. Measurement of variables ranging from point temperatures to combustion products continue to be investigated. Activities in FY 1992 included qualitative imaging of flow fields with high resolution video cameras, infrared image acquisitions, planar imaging of Raleigh scattering using pulsed laser sources, and soot transmission, scattering and sampling.

Advanced Furnace Technology

A furnace processing concept for conductive materials was developed and demonstrated by applying magnetic fields to a melted test sample during processing. The primary purpose was to provide a counteracting force which, when imparted to the melted sample, suppresses the fluid flow produced by effects such as residual low gravity accelerations and surface tension driven convection forces. The resulting crystal is expected to be of improved structure.

Stereo Imaging Velocimetry

Three dimensional flow velocity mapping of fluids can be accomplished through the simultaneous mapping and tracking of multiple tracer particles whose locations are determined from two camera images. In the first year of this technology development, various processing algorithms were studied and implemented to enable particle centroid and edge tracking to be accomplished. Particle tracking algorithms are fundamental to the imaging capability. One use of this technology involves multi-point particle tracking during convective flow studies on fluids.

Laser Light Scattering Instruments

Sturdy, miniaturized Laser Light Scattering instrumentation and operational software have been developed. This year, a single angle detector system was delivered and evaluations begun. Also, advances were made in the use of back-scatter probes in studies of nontransparent solutions. Applications are as diverse as sensing nucleation and diffusion, and studies of cataracts.

Surface Light Scattering Instruments

Development has begun of an instrument capable of detecting fluid surface phenomena such as local temperatures and interface temperature gradients, surface tensions, and volume viscosity. Initial work has included surface light scattering data collection using laboratory systems and development of the theoretical equations to accomplish measurements on curved surfaces.

Multizone Transparent Furnace

Development of a multizone transparent furnace was concluded. The objective was to create a controllable multizone furnace, while providing a view of the sample. A transparent, multizone-controlled, modular furnace system for use in materials processing experiments was developed and demonstrated. Various video imaging processes were applied and evaluated to determine the sample interface shape.

Multicolor Holography

A non-contact method of simultaneously determining concentration

and temperature variations in fluid systems is underway. Confirmation of the capability to measure fringe lines to sufficient resolution was made this year. This capability will provide the ability to continue with full measurement system development. Two fluid parameters will be varied simultaneously, while this technique will measure the variations by using two different frequency lasers. More complete multi-variable research on fluid science experiments will be enabled by this new capability. An added benefit will be the additional simultaneous data acquisition capability and thus possibly a reduction in the number of experiment runs required per mission.

Table 6.1 Advanced Technology Development funded by MSAD in FY 1992

Non-Contact Temperature Measurements	Ali Abdi Jet Propulsion Laboratory Pasadena, CA
Microwave Furnace Development	Dr. Martin B. Barmatz Jet Propulsion Laboratory Pasadena, CA
Ultrasonic Interface Measurements of Crystal Growth	Dr. Archibald L. F. NASA Langley Research Center Hampton
Microgravity Fluids and Combustion Diagnostics	Paul S. Greenberg NASA Lewis Research Center Cleveland, OH
Advanced Furnace Technology	Dr. Sándor L. Lénárd NASA Marshall Space Flight Center Huntsville
Stereo Imaging Velocimetry	Mary Jo B. Meyer NASA Lewis Research Center Cleveland, OH
Laser Light Scattering Instruments	Thomas K. Glasgow NASA Lewis Research Center Cleveland, OH
Surface Light Scattering Instruments	Thomas K. Glasgow NASA Lewis Research Center Cleveland, OH
Multizone Transparent Furnace	Bruce N. Rosen NASA Lewis Research Center Cleveland, OH
Multicolor Holography	William K. Witherow NASA Marshall Space Flight Center Huntsville, AL

ADDITIONAL TECHNOLOGY RESEARCH AND DEVELOPMENT

Other technology research and development areas sponsored by MSAD include several research studies that addressed important science and technology issues related to containerless processing of materials in the microgravity environment. In one investigation, experimental and theoretical work was carried out in ultrasonic levitation, undercooling, and dendritic solidification of succinonitrile, a transparent model material used to simulate the solidification behavior of metals and alloys. Another effort focused on research in containerless processing using electrostatic levitation. Electrostatic levitation and positioning was attractive because of the potential for highly stable sample positioning, and because it is the only approach that can levitate a wide variety of sample materials, including non-electrically conducting materials, in a high vacuum. In FY 1992, this research has resulted in a laboratory capability in the levitation of samples at high temperatures (2000 deg. C) where the levitation and melting of Nickel at 1500 deg. C was demonstrated.

MICROGRAVITY EXPERIMENT HARDWARE FOR SPACE SHUTTLE FLIGHTS

A significant effort was spent in preparation for a number of Space Shuttle missions that are described in Section 5.0. The multiuser and experiment-unique apparatus flown aboard the Shuttle will be flown periodically over the next six years in three payload configurations: 1) the International Microgravity Laboratory (IML) first flown in January 1992, 2) the U.S.-dedicated Spacelab Microgravity Laboratory (USML) first flown in June 1992, and 3) the U.S. Microgravity Payload (USMP), the non-pressurized system resident in the STS payload bay first flown in September 1992. The IML and USML laboratories, and USMP flight configurations are currently manifested through 1997, with change-outs planned to accommodate new experiments. Table 6.2 lists the flight experimental apparatus that has been in use and under development in the Microgravity program.

Table 6.2 MSAD Flight Experiment Hardware and Facilities

Advanced Automated Directional Solidification Furnace (AADSF): The AADSF is a modified Bridgman-Stockbarger furnace for directional solidification and crystal growth.

Critical Fluid Light Scattering Experiment (CFLSE): The CFLSE apparatus provides a controlled thermal environment and dynamic light scattering and turbidity measurements for critical fluid experiments.

Crystal Growth Furnace (CGF): The CGF is a modified Bridgman-Stockbarger furnace for crystal growth from the melt or vapor.

Drop Physics Module (DPM): The DPM is designed to investigate the surface properties of various suspended liquid drops, to study surface and internal features of drops that are being vibrated and rotated and to test a new technique for measuring surface tensions between two immiscible (unmixed) fluids.

Droplet Combustion Experiment (DCE): The DCE apparatus is designed to study droplet behavior during combustion by measuring burning rates, extinction phenomena, disruptive burning, and soot production.

Fluids Experiment System (FES): The FES is a multipurpose fluids research apparatus that uses schlieren and holographic imaging to investigate the effects of microgravity on transparent fluids.

Glovebox Experiment Module: The Glovebox facility is designed to provide an enclosed working area for experiment manipulation and observation and provides multipurpose filters, thermal controls, sensors, valves, and ports for air-tight gloves and cuffs.

Isothermal Dendritic Growth Experiment (IDGE): The IDGE apparatus is being developed to study the growth of dendritic crystals in transparent materials that simulate some aspects of pure metals and metal alloy systems.

Lambda Point Experiment (LPE): The LPE hardware is used for the study of critical phenomena in liquid helium.

Low Temperature Research Facility (LTRF): LTRF is a multidisciplinary experimental flight facility dedicated to fundamental scientific investigations at low temperature in reduced gravity environments.

Pool Boiling Experiment (PBE): The PBE apparatus is capable of autonomous operation for the initiation, observation, and recording of nucleate pool boiling phenomena.

Programmable Multi-Zone Furnace (PMZF): A PMZF could be a versatile tubular furnace for solidification studies, using a large number of independently controlled axial heater elements to generate the furnace temperature profile.

Protein Crystal Growth (PCG): The PCG apparatus is being developed to evaluate the effects of gravity on the growth of protein crystals.

Solid Surface Combustion Experiment (SSCE): The SSCE is designed to determine the mechanism of gas-phase flame spread over solid fuel surfaces in the absence of buoyancy-induced or externally imposed gas-phase flow.

Space Acceleration Measurement System (SAMS): The SAMS apparatus is designed to measure and record the acceleration environment in the Space Shuttle Middeck and cargo bay, and in Spacelab.

Surface Tension Driven Convection Experiment (STDCE): The STDCE apparatus is designed to provide fundamental knowledge of thermocapillary flows, fluid motion generated by the surface attractive force induced by variation in surface tension caused by temperature gradients along a free surface.

MICROGRAVITY SCIENCE PROGRAM PLANNED FOR SPACE STATION FREEDOM

Space Station Freedom will provide a stable platform on which highly productive and flexible microgravity science experiment modules can be based. A key long term program goal is the development of several multiuser facilities specifically designed for long duration scientific research missions aboard the Space Station. To obtain an optimal balance between science capabilities, costs, and risks associated with the design of the precursor flight experiments and modules, MSAD has coordinated facility requirements definition with evolving Space Station capabilities. In addition, MSAD has enhanced its research base to gain sufficient on-orbit experience in order to apply valuable "lessons learned" from early flight experiments before fully committing to extensive facility hardware design.

MSAD is defining initial requirements for six multiuser facilities for the Space Station:

- Protein Crystal Growth Facility
- Biotechnology Facility
- Space Station Furnace Facility
- Fluid Physics/Dynamics Facility
- Modular Combustion Facility
- Modular Containerless Processing Facility

The Advanced Protein Crystal Growth Facility originally planned for early deployment on the Space Station as a multiuser facility for protein growth has been deferred until later in the utilization of Space Station. When completed, it is envisioned to be a double equipment rack supporting up to four experiment modules, each with different capabilities. The current Space Shuttle Protein Crystal Growth Facility will be adapted for the Space Station, occupy a half rack and is planned for 1997.

The Biotechnology Facility will accommodate Bioreactor systems to address cell growth, cell fusion, and the electro-hydrodynamic nature of cell separation using the quiescent low-gravity environment of Space Station. It is a modular facility occupying a single experiment rack. Test apparatus consists of one module, divided into two sections. One

section contains the reactor vessel, other fluid filled components, a light and vessel drive motor. The other section contains a camera, tape supply, control electronics, and power supply. Current efforts are focused on expanding the ground-based program relative to these research areas and conducting focused flight technology demonstrations in advance of flight experiments. The Biotechnology Facility is scheduled to be on Space Station Freedom in 1997.

The Space Station Furnace Facility, scheduled for 1998, is a modular facility designed to accommodate investigations in basic materials research, commercial applications, and studies of phenomena involved in the solidification of metals and semiconductor materials. The Space Station Furnace Facility is comprised of furnace modules and a core of integrated support subsystems. The Space Station Furnace Facility has also been serving as a pathfinder for all other MSAD Space Station-bound payloads. The Space Station Furnace Facility Project has performed extensive coordination with the various Space Station Work Packages to ensure that payload requirements are incorporated in the Space Station design process.

The Fluid Physics and Dynamics Facility is expected to accommodate a range of microgravity fluids experiments such as multiphase flow, free surface phenomena, immersed bubble/droplet interactions, and thermophysical property measurements. The Fluid Physics and Dynamics Facility is planned for an initial flight aboard the Space Station in the year 1999. As precursors to the Fluid Physics and Dynamics Facility, advanced fluids experiment hardware is presently being defined for Spacelab missions in the mid-1990s.

The Modular Combustion Facility will support a wide range of science experiments dealing with the study of combustion and its by-products. The facility is currently planned for flight aboard the Space Station in the U.S. Laboratory Module in 1999. Advanced combustion experiment hardware is presently being defined for Spacelab missions in the mid 1990s as precursors to the Modular Combustion Facility experiments.

The Modular Containerless Processing Facility, a multiuser facility for the Space Station in which different non-contact sample positioning approaches may be used to study the processing of various materials over a wide range of temperatures, was planned. This facility may also be used to conduct drop coalescence and interaction studies. In addition, the feasibility of a Biotechnology Facility, in which cell growth, cell fusion, and various biological component separation techniques might be studied, continues to be evaluated. Studies to define the science requirements for these two facilities continued in FY 1992.

GROUND-BASED MICROGRAVITY RESEARCH SUPPORT FACILITIES

NASA has reduced-gravity research facilities that support the MSAD Microgravity Research Program. The ground facilities include three drop towers, wherein the sample and equipment can be protected from the drop environment, at Lewis Research Center and Marshall Space Flight Center. Aircraft in parabolic flight trajectories can provide even longer microgravity durations; a KC-135 aircraft at the Johnson Space Center and a Learjet Model 25 at the Lewis Research Center are available. Each of these facilities provides a reduced-gravity environment of varying duration. Table 6.3 summarizes the use of these facilities in FY 1992. The 145 meter drop tower at LeRC was closed for refurbishment. The Microgravity Materials Science Laboratory at the Lewis Research Center continued to provide an extensive computational and modeling capability.

Table 6.3 Use of Ground-Based Low-Gravity Facilities

	2.2 Sec. Tower	KC-135	Learjet
No. of Investigations Supported	23	30	6
No. of Drops or Trajectories	883	1898	313
No. of Flights (Flight Hours)	n/a	45 (77)	78 (118)

EDUCATIONAL OUTREACH ACTIVITIES

Communicating the objectives and results of the MSAD microgravity program through educational outreach was also a major activity during FY 1992. A secondary-level "Teacher's Guide on Microgravity" was developed, published and made available to thousands of secondary-level educators. This 50 page guide contained a primer covering the various microgravity disciplines as well as a dozen different demonstrations designed to be performed in any class room.

In late June and early July, fifteen "Today in Space" NASA Select television productions describing the USML-1 microgravity investigations were developed and aired. Similar productions were aired during the IML-1 and SL-J missions. A special NASA Education Satellite Teacher Video Conference on Microgravity, accessible to over 10,000 schools across the United States, was broadcast on December 15, 1992.

MSAD also developed a poster on the influence of gravity as part of an eight poster set called "Perspective from Space," developed by NASA as a contribution to public understanding of space science in the spirit of

International Space Year. In FY 1992, MSAD supported two students (University of Michigan and Colorado State University) in the NASA Graduate Student Researchers Program (GSRP), which attempts to reach a culturally diverse group of promising U.S. graduate students whose research interests are compatible with NASA's programs in space science and aerospace technology.

MICROGRAVITY DATA ARCHIVING

In FY 1992, MSAD conducted a study to determine the requirements for microgravity science data archives. The study was conducted by scientist from the Lewis Research Center, Marshall Space Flight Center, and the National Institute of Standards and Technology. The study's recommendations have been accepted and pilot archives are currently under development.

SECTION 7: Microgravity Program Resources for 1992

Funding for the FY 1992 MSAD microgravity science and technology program totaled \$120.8 million. This budget supported an array of activities including an extensive microgravity research program, development and flight of three microgravity dedicated Space Shuttle missions, participation in SL-J, Space Station Freedom planning, technology and hardware development, and educational outreach. The funding distribution for the microgravity research disciplines is illustrated in Figure 1. This figure represents both the flight and ground microgravity research efforts.

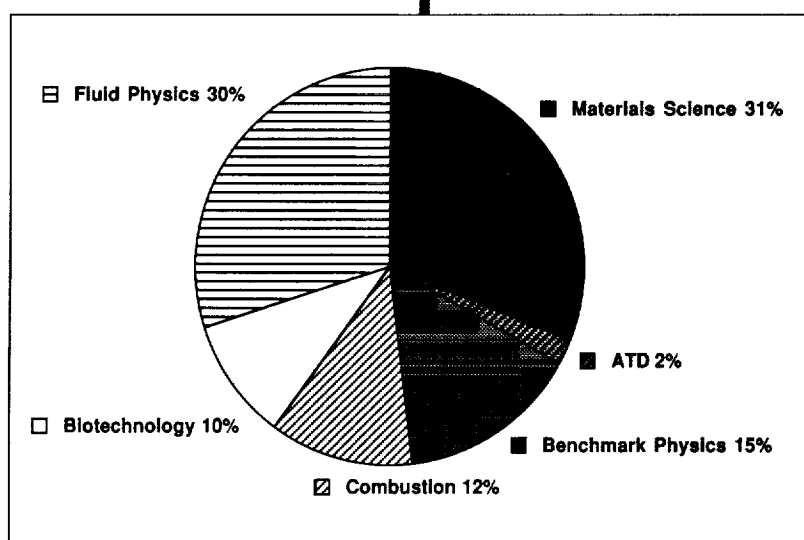


Fig.7.1 (Above) FY 1992 Microgravity Funding Distribution by Science Discipline: \$120.8M

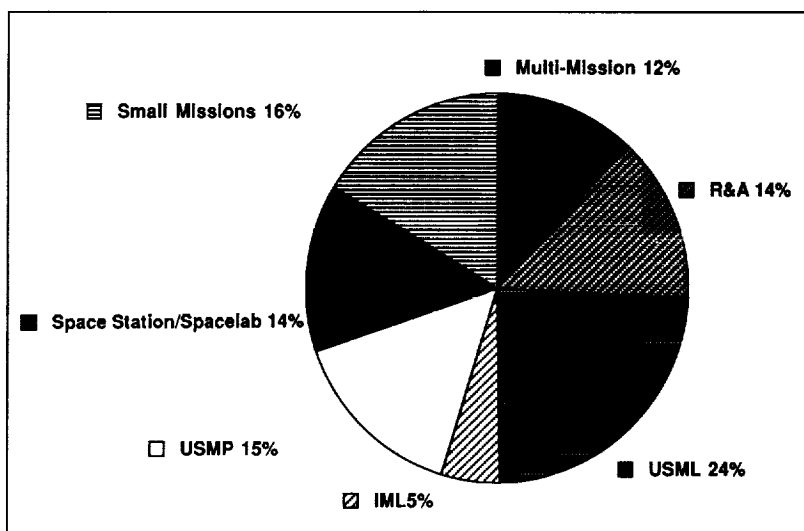


Fig.7.2 (Above) FY 1992 Microgravity Funding Distribution by Mission Series: \$120.8M

Figure 2 presents the funding distribution by microgravity mission. Included in this representation is the Research and Analysis (R&A) element that supports the microgravity principal investigators not covered in a mission specific budget. The Multi-Mission category includes other costs that are not identified with a specific mission. These costs include administration, the advanced technology development program, the Space Acceleration Measurement System program, data management and archiving, and infrastructure. The Small Missions element is the portion of the microgravity research program that use the Space Shuttle Small Payload Systems (e.g., Get Away Special Program), Shuttle Middeck experiments, and sounding rockets. The Space Station/Spacelab element represents funding for experiments that are planned for Space Station Freedom, but could be conducted on the Spacelab with little or no modification. Included in this category are the combustion and fluids modules, the Modular Combustion Facility, the Fluid Physics and Dynamics Facility, the Biotechnology Facility, Protein Crystal Growth, and Space Station Furnace Facility modules.

The MSAD microgravity research program operates through five NASA Field Centers and Figure 3 illustrates the

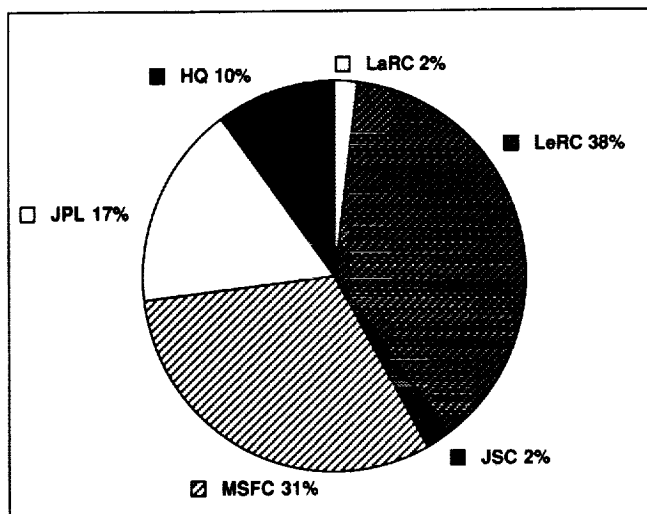


Fig.7.3 FY 1992 Microgravity Funding Distribution by NASA Field Centers: \$120.8M

funding distribution among these centers. The microgravity effort at Lewis Research Center is focused on Combustion Science and Fluid Physics. The effort at the Marshall Space Flight Center is focused on Materials Science and the protein crystal growth portion of the Biotechnology discipline, while the effort at the Johnson Space Flight Center is focused on the cell culture portion of the

Biotechnology discipline. The Jet Propulsion Laboratory effort is focused on containerless processing and low temperature physics. Technology development tasks were also funded in FY 1992 at each of the field centers.

APPENDIX: **Acronyms and Abbreviations**

AADSF	Advance Automated Directional Solidification Furnace
ADSF	Automated Directional Solidification Furnace
AO	Announcement of Opportunity
ATD	Advanced Technology Development
BTF	Biotechnology Facility
CCDS	Center for the Commercial Development of Space
CFTE	Critical Fluid Thermal Equilibrium
CGF	Crystal Growth Furnace
CNES	Centre Nationale d'Études Spatiales (The French Space Agency)
CPF	Critical Point Facility
CSA	Canadian Space Agency
DARA	Deutsche Agentur für Raumfahrtangelegenheiten (German Space Agency)
DPM	Drop Physics Module
DWG	Discipline Working Group
ESA	European Space Agency
FEA	Fluids Experiment Apparatus
FPDF	Fluid Physics and Dynamics Facility
FY	Fiscal Year
GaAs	Gallium Arsenide
HSA	Human Serum Albumin
IDGE	Isothermal Dendritic Growth Experiment
IML	International Microgravity Laboratory
JEA	Joint Endeavor Agreement
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Flight Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LeRC	Lewis Research Center
LLSI	Laser Light Scattering Instrumentation
LPE	Lambda Point Experiment
MCF	Modular Combustion Facility
MCPF	Modular Containerless Processing Facility
MMSL	Microgravity Materials Science Laboratory
MSAD	Microgravity Science and Applications Division
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NASDA	The National Space Development Agency
NCTM	Non-Contact Temperature Measurement
NIST	National Institute of Standards and Technology
NRA	NASA Research Announcement
OACT	Office of Advance Concepts and Technology
OSSA	Office of Space Science and Applications
PCG	Protein Crystal Growth

PI	Principal Investigator
PIV	Particle Image Velocimetry
SAMS	Space Acceleration and Measurement System
SSCE	Solid Surface Combustion Experiment
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
STDCE	Surface Tension Driven Convection Experiment
STS	Space Transportation System
TEA	Technical Exchange Agreement
UAH	University of Alabama - Huntsville
USML	United States Microgravity Laboratory
USMP	United States Microgravity Payload
VIT	Vibration Isolation Technology